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An Economic Analysis of GRDC Investment in Reducing Salinity and Recharge in Cropping Areas

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Impact Assessment:
Economic Analysis of GRDC Investment in Reducing Salinity and Recharge in Cropping Areas

Executive Summary

A range of remedial options was identified in the 1990s for potentially reducing groundwater recharge and associated dryland salinity. One of these options was the use of perennial plants, particularly deep-rooted perennials that could be integrated with cropping systems and utilise more water during the summer growing season. The eight projects analysed in this cluster were directed at assisting grain producers increase profitability and prevent or slow salinisation from the use of perennial pastures with a number specifically directed at the use of lucerne in crop rotations. The investment in the cluster spanned the period from the year ending June 2000 to the year ending June 2005, with most investment occurring in the middle four years. Most of the projects were undertaken in Western Australia.

The most important output from the investment was the extension of the knowledge base for integrating lucerne into farming systems in southern cropping regions (predominantly winter cropping). The investment has raised awareness of opportunities and potential profitability and provided greater confidence for cropping farmers to invest in lucerne as a deep rooted perennial.

Assumptions are difficult to make regarding likely adoption of lucerne and its integration into cropping systems as a result of the investment. Firstly, it appears there is a wide range in the increase in farm profitability of integrating lucerne into the cropping system. However, from the analyses undertaken elsewhere there appears little doubt that increased whole farm profitability is likely, but this conclusion is dependent on the type and profitability of the livestock production system in which the lucerne is utilised.

The impact of lucerne on groundwater recharge has been confirmed where the lucerne is grown on farm, but large area impacts particularly where regional and intermediate groundwater systems exist are likely to require significant areas of lucerne planted in the area to make much difference. Given that the optimal area from a profitability viewpoint is some 5-30% of the farm planted to lucerne, it is unlikely that widespread groundwater control is likely.

Based on a conservative estimate of the profitability gain likely and assumptions on the area that has been, and will be, planted to lucerne over the next twenty years, the investment is considered to have been profitable with a total net present value estimated at $7m. The investment is estimated to provide a benefit-cost ratio of 1.5 to 1 and an internal rate of return of just below 8%.

1 Introduction

Dryland salinity is caused by widespread landscape change resulting from new forms of land management since European settlement. The use of annual crops and annual grasses and legumes has exacerbated the impact of removal of water-using deep-rooted perennials on farming land. This has led to rising watertables and, in many cases, these have brought salt from lower levels to the surface or close to it. Some of this salt can be transported to waterways so affecting water quality. Most of the dryland salinity areas are in Western Australia and are having, and are likely to have in future, a significant impact on winter grain production. Other grain growing areas affected are in South Australia, northern Victoria and southern NSW. Salinity continues to expand in Western Australia but at a rate lower then had been experienced previously. Part of this change is due to the lower average rainfall since the year 2000.

A range of remedial options has been identified, including retaining and re-invigorating remnant vegetation, establishing and enhancing perennial pastures, phase farming and intercropping with lucerne, opportunity cropping and farm forestry, different types of drains, banks and wells, as well as managing land that has already become salinised. The projects analysed in this cluster are directed at preventing or slowing salinisation from the use of perennial pastures and more specifically at the use of lucerne in crop rotations.

The eight projects included in the current analysis spanned the period from the year ending June 2000 to the year ending June 2005, with most investment occurring in the middle four years.

Previous to the year 2000, the most popular option to reduce recharge to the water table in southern cropping areas was to plant trees. GRDC had invested heavily in research aimed at systems of reducing recharge with deep rooted perennials compatible with crop production. A number of cropping farmers had incorporated lucerne into their rotations particularly in Western Australia and southern NSW. However, the perceived lack of economic benefits was a constraint to many farmers advancing this practice.

The research described in this cluster of projects was aimed at expanding knowledge associated with different systems of incorporating lucerne and other perennials from the point of view of whole farm system profitability as well as effectiveness in drawing down the water table. Systems explored in more detail than hitherto included: summer grain crops, summer forage crops (including intercropping, phase farming and overcropping with lucerne), and perennial grain crops. In addition, other projects included aids for management decisions (farm scale salt mapping using airborne geophysical surveys and farm and catchment scale models for analysis of different revegetation schemes in salinised and waterlogged areas).

2 Project Investment

Overall Objectives

The overall objective of the investment in this series of projects was to increase knowledge of methods for cropping farmers to respond to the growing threat of salinity and waterlogging through decision aids (improved cropping systems that utilised more water during the summer growing season as well as mapping and modelling aids).

Projects Funded by GRDC
Eight projects were funded by GRDC in this investment cluster as listed in Table 1. Table 2 provides a summary of the objectives of each project.

Table 1: Water Recharge Management Projects Funded by GRDC

Project Code and Title	Other Details
DAW659: Farming Systems with Lower Recharge for WA	Western Australian Department of Agriculture July 1999 to June 2000 Jon Warren
DAW722: Warm season cropping systems on the south coast of WA	Western Australian Department of Agriculture July 2000 to June 2004 David Hall
UWA345: Lucerne intercropping for sub-soil water management	CSIRO Sustainable Ecosystems July 2000 to June 2004 Ted Lefroy
DAV453: Increasing lucerne adoption in farming systems: an integrated approach	Victorian Department of Natural Resources and Environment July 2001 to June 2004 Michael Crawford, Kieran Ransom
UWA339: Low recharge farming systems for the southern wheat belt of Western Australia based on lucerne	University of Western Australia July 2000 to June 2005 Perry Dolling (Western Australia Department of Agriculture) (for a period was temporarily managed by DAWA due to staff departures).
BRS00005: Targeting salinity at the farm-scale: empowering landholders through practical interpretation of airborne geophysical surveys	Bureau of Rural Sciences July 2002 to June 2004 Richard Cresswell
RDC10: Contribution towards UWA60A: Perennial grain crops for high water use.	University of Western Australia July 2000 to June 2004 Ted Lefroy
LWR20: Contribution towards UMU17: A simple computer program for dryland salinity management Australian wide (FLOWTUBE)	Murdoch University July 2000 to June 2004 Richard Bell

Table 2: Project Codes, Titles and Objectives

Project Code and Title	Stated Objectives
DAW659: Farming Systems with Lower Recharge for WA	(i) To develop, test and validate through participative R&D viable new cropping systems with lower groundwater recharge than current systems.
DAW722: Warm season cropping systems on the south coast of WA	(i) Develop a risk analysis of warm season cropping for the south coast region of Western Australia to arrive at best bet options for maximising summer and winter crop productivity and minimising deep drainage. (ii) Develop hard data on the performance of warm season crops on the south coast of Western Australia and on best practice agronomy to impact on production and on farming systems. (iii) Develop a best management practice manual for warm season crops and a technical report on data collected and collated for the project.
UWA345: Lucerne	(i) To determine the distance required between intercropped lucerne rows

intercropping for sub-soil water management	to reduce median deep drainage to less than 5% of annual rainfall on soils with high and low clay content. (ii) To quantify the impact on grain yield and gross margin of crop displacement, competition and additional management associated with intercropping compared to phase farming (iii) Determine the effectiveness and cost per ha of defoliants required to eliminate green sample at harvest.
DAV453: Increasing lucerne adoption in farming systems: an integrated approach	(i) To develop farmer, researcher and technical adviser networks to facilitate the adoption of lucerne into farming systems in parts of the NSW-VIC Slopes, SA-VIC Bordertown-Wimmera and SA-VIC Mallee zones. (ii) To validate and adapt component research relating to lucerne phase farming, and hence develop appropriate management guidelines for lucerne in crop rotations for these zones. (iii) To undertake whole farm economic analyses that consider the benefits, costs and risks of moving from current systems based on ley pastures to one based on phase farming.
UWA339: Low recharge farming systems for the southern wheat belt of Western Australia based on lucerne	(i) To monitor the impact of phase farming with lucerne and to address systems-related problems associated with its introduction to Western Australia. (ii) To coordinate the Western Australian Lucerne Growers Group and to extend the results of this and other projects on phase farming with lucerne to the farming community. (iii) To directly provide advice to growers regarding establishment of lucerne in Western Australia.
BRS00005: Targeting salinity at the farm-scale: empowering landholders through practical interpretation of airborne geophysical surveys	(i) To improve farmer knowledge and interpretation of salt mapping at the farm and paddock scale. (ii) To convey to farmers information about salt mapping products and methods for application at paddock scale.
RDC10: Contribution towards UWA60A: Perennial grain crops for high water use	(i) Screen potential relatives of the major grain crops (wheat, barley, rye) plus high seed-yielding naturalised and endemic perennial grasses for their potential as grain crops.
LWR20: Contribution to UMU17: A simple computer program for dryland salinity management Australian wide (FLOWTUBE)	(i) Continue the development of the FLOWTUBE model so that it can simulate the eastern states conceptual models in addition to those of Western Australia. (ii) Carry out thorough testing of the model for both eastern states and Western Australia by running each of the models using local data and appropriate / representative treatments. (iii)Investigate, for at least some of the conceptual models, how the linear prediction by FLOWTUBE of shallow water tables along a flow line in the catchment relates to the area of the catchment that will have a shallow water table as predicted by more complex 3 dimensional models. (iv) Encourage adoption of the model by interested stakeholders in land management agencies by carrying out training it is use.

Investment Inputs

Estimates of the funding by project by year by GRDC for each of the eight projects are provided in Table 3.

Table 3: Investment by GRDC by Project for Years ending June 2000 to June 2005 (nominal $)

Project	99/00	00/01	01/02	02/03	03/04	04/05	TOTALS
DAW659	250,000	250,000	250,000	250,000	250,000	0	1,250,000
DAW722	0	50,000	143,800	152,000	153,600	0	499,400
UWA345	0	120,770	108,944	112,210	115,579	0	457,503
DAV453	0	0	110,000	118,300	116,699	0	344,999
UWA339	0	42,708	100,000	100,000	100,000	0	342,708
BRS00005	0	0	0	133,988	162,019	0	296,007
RDC10/ UWA60A	0	33,700	34,743	27,056	6,402	0	101,901
LWR20/ UMU17	0	8,906	27,084	30,724	29,095	0	95,809
Totals	250,000	506,084	774,571	924,278	933,394	0	3,388,327

Source: GRDC

There also were in-kind contributions from the research partners. Table 4 provides estimates of the partners' total investment in each of the eight projects for each year and Table 5 the combined GRDC and partner investment for each year. It is of interest to note that two projects involved joint funding with other RDCs.

Table 4: Investment by GRDC Partners by Project for Years ending June 2000 to June 2005 (nominal $)

Project	99/00	00/01	01/02	02/03	03/04	04/05	TOTALS
DAW659	330,260	563,570	571,945	586,215	603,693	0	2,655,684
DAW722	0	58,695	168,807	178,433	180,311	0	586,246
UWA345	0	141,078	145,311	149,669	154,162	0	590,221
DAV453	0	0	172,051	185,033	182,529	0	539,613
UWA339	0	77,000	115,200	119,700	123,900	128,200	564,000
BRS00005	0	0	0	139,500	208,500	0	348,000
RDC10/ UWA60A	0	42,750	44,065	36,657	6,402	0	129,874
LWR20/ UMU17	0	84,635	104,815	97,281	66,823	0	353,554
Totals	330,260	967,728	1,322,194	1,492,488	1,526,320	128,200	5,767,192

Table 5: Investment by GRDC and Others in Eight Projects for Years ending June 2000 to June 2005 (nominal $)

Year	99/00	00/01	01/02	02/03	03/04	04/05	TOTALS
GRDC	250,000	506,084	774,571	924,278	933,394	0	3,388,327
Partners	330,260	967,728	1,322,194	1,492,488	1,526,320	128,200	5,767,192
Total	580,260	1,473,812	2,096,765	2,416,766	2,459,714	128,200	9,155,519

Source: Partners' investment based on project proposals

3 Outputs

A summary of the principal outputs from each of the eight projects is reported in Table 6.

Table 6: Summary of Principal Outputs by Project

Project	Principal Outputs
DAW659	(i) Used participatory research approach and include trials to assess cover cropping, over cropping, use of lucerne (hay and grazing), and lucerne establishment and management. (ii) Used simulation modelling (APSIM) and addressed hydrological imbalances and farm profitability. (iii) Improved knowledge regarding plant water use. (iv) Produced protocols for lucerne experiments. (v) Integrated findings with other lucerne projects. (vi) Chemicals used to kill or suppress lucerne at the end of the pasture phase had no effect on subsequent crop yields.
DAW722	(i) Simulation modelling (APSIM) was central to the risk analysis. (ii) Summer forage crops produced profitable yields in all years; sorghum grain yields were profitable once in 3 to 5 yrs. (iii) Summer crops reduced recharge by 3-20 mm per year. (iv) Ability to dry profiles was less for crops than for lucerne. (v) Best practice manual for warm season crops completed. (vi) Addressed issues of weeds, disease, salinity, waterlogging, and increasing profitability. (vii) Drainage results show that recharge is dominated by large episodes in wet years; use of summer crops reduced deep drainage but could not eliminate it. (viii) Training kit produced. (ix) Economic analysis completed (Michael O'Connor) including gross margins.
UWA345	(i) Comparisons reported between strip cropping, phase farming and intercropping with regard to grain yield and water management. (ii) Only intercropping was able to limit drainage to 10% or less of annual rainfall, suggesting that integration of lucerne into cropping systems may be more effective in water management than phase farming. (iii) Average grain yields were higher for intercropping and strip cropping than for the phase system. (iv) Profitability of systems was sensitive to the value placed on lucerne which depended on the nature of the livestock enterprise.
DAV453	(i) A whole farm economic assessment framework developed for application to lucerne phase farming systems in northern Victoria. (ii) Analysis of profitability of 14 case study farmers before and after

	incorporating lucerne into cropping rotations. (iii) Incorporation of lucerne increased profitability by 9-200% through increased cropping intensity, improved grain quality (protein increased 1-2%) and increased stocking rate (38-260%). (iv) Before the project specific information was poor and a significant constraint to adoption. In most cases it had taken at least a decade for farmers to develop sufficient confidence to fully implement their lucerne production systems. (v) Produced a lucerne management booklet for managing lucerne in a crop rotation and for optimising water use and maximising benefits to following crops; booklet covers varieties, establishment and grazing management, timing and method of lucerne removal, intercropping and nitrogen and weed management of crops after lucerne. (vi) Lucerne Links newsletter produced.
UWA339	(i) Supported Western Australian Lucerne Growers (WALG) group to act as an extension pathway for information on lucerne management. (ii) Trials with lucerne grower collaborators verified research based information at paddock scale, including information on number of crops following lucerne, impact on water and nutrient balances, utilisation such as livestock or green manure systems, economic returns compared to continuous cropping, and herbicide resistance. (iii) Project complemented research project (UWA 149). (iv) Supported WALG newsletters. (v) Compiled lucerne technical bulletin. (vi) Pasture production and grain yields were similar or higher in the lucerne rotation compared to an annual system. (vii) Establishment of lucerne with a cover crop had potential. (viii) Possibility for overcropping established lucerne was established. (ix) Phase farming with lucerne was considered more suited to cropping systems in drier regions.
BRS00005	(i) An interactive geographic information system (GIS) mapping and data CD toolkit was produced to help farmers make informed management decisions about salinity. (ii) Series of workshops with local grower groups held in SA to explain the kit and demonstrate methods of ground calibration to landholders. (iii) Incorporates instructions on water level measurements in bores, comparisons with rainfall records, measurement of salt stream loads and salt mass balance dynamics at farm scale. (iv) The tool could pinpoint areas of higher conductivity and where adverse impacts on productivity may occur at the paddock level and so be used in prioritising future management activities. (iv) Methods could be used in other areas and similar products developed. (v) Used group consultations and workshops. (vi) Training carried out on use of water level sampling devices, and recording and analysis of data.
RDC10/ UWA60A	(i) Review of perennial grain crops research showed that long life and high seed yield are not necessarily mutually exclusive. (ii) Some perennial crops had yielded in excess of 1 t per ha in USA. Also there could be niches where low grain yields could be compensated by grain value or by grazing value in summer period. (iii) Identified Australian native species *Microlaena stipoides* (weeping rice grass) as having potential as it has large seeds like

	rice. (iv) Large variation in seed yield for *Microlaena* so yield improvement through selection likely; twenty fold range in seed yields identified; high protein content; most likely gluten free. (v) Conceptual plan produced for assessing commercialisation potential. (vi) Symposium held at UWA in Late September 2004.
LWR20/ UMU17	(i) The original FLOWTUBE model was developed by CSIRO and had been used in a number of modelling activities such as the WA State Salinity Strategy in 1999 (Bell, pers.comm., 2008). (ii) Further development of the FLOWTUBE model took place in this project making it work for all conceptual models and useful to eastern states as well as further refined for Western Australia. (iii) Model was successfully extended and algorithms demonstrated successfully for some conceptual models. (iv) Model now simpler to use for estimating effect of interventions on groundwater. (v) Designed for use at catchment scale, but can be used for particular sites or farm planning under some circumstances. (vi) Program delivered to training courses.

4 Outcomes

A summary of the principal outcomes from each of the eight projects is reported in Table 7.

Table 7: Summary of Principal Outcomes by Project

Project	Principal Outcomes
DAW659	(i) Improved appreciation by cropping farmers of lucerne as a potentially viable component of cropping systems for lower rainfall areas of wheat belt of WA. (ii) Barriers and key issues were addressed and the value of lucerne in filling major feed gaps was identified as a key driver of profitability. (iii) In general wheat and lucerne yields each declined when grown together. (iv) Resulted in minimal additional lucerne plantings, perhaps of the order of 10 to 30 growers who worked with the project (Jon Warren, pers. comm., August 2008). Lucerne did not fit particularly well with the majority of farming systems. (v) Major lesson learnt was that innovative farmers are not the best members of participatory research projects as they move on quickly (Jon Warren, pers. comm., August 2008). (vi) Project was terminated due to all milestones not being met.
DAW722	(i) Project highlighted the risk of growing summer grain crops compared to summer forage crops (David Hall, pers. comm., August, 2008). (ii) Lucerne generally outperformed summer crops regarding both profitability and reducing recharge rates. (iii) Likely flow-on to other regions of WA from point of view of increased confidence, reduced risk and benefits from diversification of income. (iv) Economic analysis provided implications for lucerne on whole of farm basis and a rational basis for promotion of lucerne. (v) Both summer grain crops and forage crops such as lucerne

	have been grown recently and opportunistically in response to recent high rainfall events (e.g. January 2007), stock feed shortages and high demand for bird seed (David Hall, pers. comm., August 2008). (vi) Contraction of livestock industries has reduced the demand for lucerne planting and other summer forages in the Esperance region (David Hall, pers. comm., August, 2008).
UWA345	(i) Potential for reduced deep drainage due to increased use of intercropping with lucerne. (ii) Lower opportunity cost of integrating perennials into cropping systems compared with phase farming. (iii) Potential for increased adoption of intercropping. (iv) A survey in 2004 reported that between 15 and 20 grain producers were experimenting with intercropping with lucerne; this number may not have changed very much since (Perry Dolling, pers. comm. to Ted Lefroy, August, 2008). (v) Intercropping increased the variability of yield for specialist grain growers. However, in high rainfall years the system produced good crop yields and green feed plus stubble (Ted Lefroy, pers. comm., August 2008). (vi) Conclusion was that it is possible to achieve the same or even slightly higher yields with intercropping compared with sole crop with very low densities of lucerne, but it is hard to achieve that density reliably. Intercropping requires specialist skills in lucerne establishment and management which is likely to deter grain growers.
DAV453	(i) Potentially more lucerne grown in Northern Victorian cropping systems resulting in less water logging, reduction in deep drainage and groundwater recharge, and enhanced profitability of grain enterprises (ii) Shifting from wool to lambs was a critical factor in increased profitability from lucerne. (iii) Timing of removal of lucerne was a key unanswered question, as was establishment in the Mallee region, and the growing of lucerne in the high rainfall zone where raised bed cropping systems are practiced. (iv) Project resulted in some new plantings of lucerne but drought and livestock prices have limited any significant new plantings in the past few years (Kieran Ransom, pers. comm., August, 2008).
UWA339	(i) Improved knowledge produced about the advantages of growing lucerne such as out of season fodder, options for disease and weed control and hay production. (ii) Potential for increased rate of adoption of lucerne in Western Australia due to greater confidence of cropping farmers in addressing lucerne issues. (iii) This project was a prime driver of lucerne adoption in WA since 2001 (Perry Dolling, pers. comm., August 2008). (iv) Potentially a reduction in recharge to groundwater reducing salinity threat on many farms and catchments if sufficient areas of lucerne are established.
BRS00005	(i) Improved farm productivity in addition to salinity mitigation by empowering farmers to adopt targeted management strategies where airborne geophysics data were available. (ii) Increased capacity to modify cropping rotations and management practices to minimise any production losses from salinity and waterlogging for some farms.

	(iii) Minimisation of scalded areas which prevents erosion and further soil degradation and encouragement of revegetation of more relevant sites with native species. (iv) Insights into landscape form and function with detailed spatial analysis of fundamental environmental features; better understanding of landscapes can lead to improved farm productivity. (v) Helped land managers understand the likely impact of planting lucerne on dewatering (Richard Cresswell, pers.comm., August 2008). (vi) Past research in NSW preceded this project and other work has followed it in South Australia.
RDC10/ UWA60A	(i) Potential identified for developing cropping potential for the perennial native species *Microlaena stipoides.* (ii) Further work required on nutritional value of seed and its grazing value. (iii) Germplasm remains property of UWA. Some seed has been distributed for assessment as a perennial forage plant. (iv) Potential spinoff is therefore a grazing cultivar with a high seed yield potentially making it more affordable than current lines; the large seed size would potentially improve germination (Ted Lefroy, pers. comm., August, 2008). (v) No adoption yet of *Microlaema stipoides* but some potential remains.
LWR20/ UMU17	(i) Model FLOWTUBE now produces information that potentially can be used to assess the likely outcomes of agronomic change on farm to recharge and salinity levels, allowing farmers to more confidently change their management practices. (ii) Application of the model may assist with management of native vegetation, at least on a catchment basis. (iii) FLOWTUBE model has been used in over 30 catchments in WA (hydrogeological processes and treatment assessments) but the model was produced and used before this investment. (iv) FLOWTUBE model is being used in several catchments in Victoria including the Wimmera, Corangamite and Glenelg Hopkins. The model can be used with farmers by a trained operator, rather than by farmers themselves.

5 Benefits

A summary of the principal types of benefits and related costs associated with the outcomes of the projects are shown in Table 8.

Table 8: Principal Benefits Emerging from the Cluster

Project	Principal Benefits
DAW659	(i) Probably no reduction over time in area of land lost to salinity through recharge as area of perennials such as lucerne required in most eastern wheat belt areas of WA would not be reached on a landscape scale and there are significant regional and intermediate groundwater systems. (ii) A small number of farms with a higher level of profitability due to planting of lucerne.
DAW722	(i) Increased profitability on a whole farm basis from use of lucerne in mixed cropping farms.

	(ii) Increase in lucerne plantings will lower recharge and associated reduced risk of salinity on an individual farm basis. (iii) Adoption restricted in past few years due to low livestock prices, but significant potential remains.
UWA345	(i) Small number of farmers using intercropping with lucerne with some increase in profitability and more reliable water management.
DAV453	(i) Increased adoption of lucerne in northern Victorian mixed cropping farms with increased farm profitability and contribution to reduced risk of recharge and salinity. (ii) Adoption restricted in past few years due to low livestock prices, but significant potential remains.
UWA339	(i) Increased adoption of lucerne in cropping systems in WA, especially in southern wheat belt with increased productivity and profitability of cropping systems (ii) Reduced recharged and potential for salinity at farm level.
BRS00005	(i) Potential for more effective landholder responses to salinity management including implications for lucerne planting (ii) Confirmation for most landholders in the project area that the actions they were undertaking were appropriate (Richard Cresswell, pers. comm., August 2008).
RDC10/ UWA60A	(i) Potential for commercialisation of a summer perennial grazing cultivar of *Microlaena stipoides* that could make a contribution to summer forage and provide potential for improved management of watertables and salinity.
LWR20/ UMU17	(i) Enhanced FLOWTUBE model accepted and used by multiple stakeholders in WA. (ii) Enhanced FLOWTUBE model adopted across Australia as a land management tool for more effectively planning interventions to limit groundwater recharge.

Productivity and Profitability Benefits

As a whole these investments have extended the knowledge of growing plants in summer to enhance profitability of cropping systems, with particular emphasis on lucerne. This has provided greater interest and confidence to those growers contemplating the introduction of a perennial to their cropping systems.

Lucerne is potentially more profitable when introduced to mixed cropping systems in the higher to medium rainfall areas, rather than to specialist cropping systems (limited livestock) or growers in the drier grain producing areas. The increase in profitability depends on the livestock system in which lucerne is utilised (e.g. higher profitability with prime lambs and lower profitability with wool).

The lower livestock profitability in recent years due to low livestock prices and drought in some areas has limited the extent of adoption of lucerne driven by these investments in the past few years, but the potential for utilising the enhanced knowledge remains if livestock prices improve. Further, the increased emphasis on livestock can reduce farm income variability through diversification.

There may be an additional productivity benefit on some specific farms establishing lucerne from reduction of waterlogging in some years as well as the possibility of avoiding or at least delaying patches of salinity that may have eventuated on the farm if lucerne had not been sown.

Environmental Benefits
The widespread use of perennials in cropping systems was initially thought to be of benefit to society as a whole. This potential environmental benefit was expected to arise from water management practices that limit run off and watertable recharge so limiting soil erosion and salt and nutrient export and hence improving water quality and biodiversity in the catchment. This benefit is thought now to be marginal and only applies locally where the lucerne is sown.

While some of the investment outcomes may have contributed to the marginal lowering of water tables where some localised groundwater systems exist, these impacts are unlikely to be significant on a catchment scale due to the relatively small areas of lucerne per farm and the low proportion of farms planting lucerne on a catchment scale. Further, the linkages between lowered watertables and any significant environmental benefits on a catchment scale cannot be confidently assumed. Due to the lack of direct evidence for these relationships these environmental benefits have not been valued in the current analysis.

Social benefits
Social benefits from planting lucerne referred to in Ransom et al (2006) include the 'oasis' factor of having green in the landscape, and hence reduced farmer stress during the summer autumn period. Further the enhanced FLOWTUBE model has been used at the catchment scale to guide more appropriate interventions regarding salinity management.

If it had been assumed that less land will be salinised and less salt exported in future from areas growing perennial pasture, the investments could have maintained or improved:

- the visual amenity value of the land to the public from potentially inhibiting or slowing salinisation.
- the option value of society of knowing that the land resource condition has greater chance of being maintained or improved.
- water quality with ensuing public benefits downstream with regard to aquatic biodiversity, water treatment costs, and infrastructure damage.

However, it is unlikely that such benefits will occur on any significant scale due to these investments.

A summary of the benefit types from the eight projects as a whole are provided in Table 9.

Table 9: Summary of Principal Benefit Types

Economic	Environmental	Social
• Increased productivity and profitability on a whole-farm basis due to integration with summer perennials, this allowing increased income from livestock that more than compensates for lost crop income from introduction of a perennial into the	• Potential for maintenance of productive capacity of land for future generations in some circumstances. • Potential for reducing or slowing the impact of salinity on native vegetation on small areas of some farms.	• 'Oasis' enhancement of visual landscapes in summer and autumn periods with reduced stress on farmers.

rotation. • Potential for alleviating waterlogging and slowing the impact of salinity on some grain producing land.		

Public versus Private Benefits
Most of the private benefits from these investments will be captured by grain producers and mixed farming systems in Western Australia (southern and south coast regions) with lesser benefits in northern Victoria, with some potential spillovers to grain producers elsewhere.

Distribution of Benefits Along the Grains Supply Chain
There may be some benefits to lucerne seed producers as the demand for sowing lucerne may increase in future in some regions. The grain price is not likely to be affected by the outcome of this research and hence there would be limited benefits to consumers.

Benefits to other Primary Industries
There will be benefits to wool, sheepmeat and beef producers who are also grain producers.

Match with National Priorities
The Australian Government's national and rural R&D priorities are reproduced in Table 10.

Table 10: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The investment has the potential to contribute marginally to National Research Priority One, with several projects also contributing to National Research Priority Three. All of the projects address Rural Research Priorities One and Three. Table 11 summarises these contributions.

Table 11: Summary of Contribution of Cluster Projects to National and Rural Research Priorities

Project	National Research Priorities	Rural Research Priorities
DAW659	1	1,3
DAW722	1	1,3
UWA345	1	1,3
DAV453	1	1,3
UWA339	1	1,3
BRS00005	1, 3	1,3
RDC10/ UWA60A	1	1,3
LWR20/ UMU17	1,3	1,3

The assessment of the relative contribution to each of the five Rural Research Priorities for the cluster as a whole is:
Rural Research Priority 1 (90%)
Rural Research Priority 3 (10%)

6 Pathway to Adoption

Most of the projects worked with grain producers and a range of publications were produced. The motivation for integrating lucerne into the cropping system has changed from one of predominantly salinity management to one of improving profitability. This has occurred due to the change in perception of the areas needed to be planted to deep rooted perennials in order to ameliorate the advance of salinity. More attention is now being given to hot spots on farms, for example with programs such as Sustainable Grazing on Saline Lands, rather than widespread planting of perennials.

The number of grain producers planting lucerne in the past few years has been constrained by drought and low prices for livestock products. Nevertheless the investment has produced knowledge and understanding of the constraints to the profitable integration of lucerne into crop rotations and has given greater confidence to grain producers in its role in a whole farm system.

One of the constraints to this assessment has been the lack of data on lucerne areas. The latest data is that for 2000/01 as the 2005/06 ABS Agricultural Census aggregated the grazed lucerne area with that of lucerne cut for hay and the two can not be separated.

There appeared little data available to substantiate assumptions regarding adoption. Some adoption to date has taken place in the areas in which the projects were located. However, much of the knowledge will be available to those in other regions grain producing areas. Assumptions on future adoption are provided in the next section.

7 Measurement of Benefits

Introduction and qualifications

The principal benefit that will be captured by this investment and which is valued in this analysis is the increased productivity from integrating lucerne into the cropping system.

Several constraints to the valuation of the productivity benefit from the investment are:
(i) Generalisations are difficult as the productivity and profitability of impacts per hectare or per farm vary considerably at whole farm level.
(ii) The eight projects included in this analysis were only a small part of the total investment that has been made into the perennial plant impact on the advance of salinity in grain producing areas so that the adoption of lucerne planting due to the project is difficult to assess.
(iii) The period since the eight projects have been completed has not been a favourable period for planting lucerne due to drought and low prices for livestock products.

Other benefits can be considered only potential and some are highly problematical. These potential benefits include:

- reduced waterlogging and delayed impact of salinity on land productivity on some farms planting lucerne.
- reduced or delayed impact of salinity on native vegetation on farms planting summer perennials such as lucerne.

While there is strong evidence that lucerne will contribute to higher water use in summer, and hence slow the rate of upward movement of the water table, there is little evidence that this can prevent salinisation in the longer term, or that catchment wide impacts will be demonstrated, even in catchments with localised groundwater systems. These potential benefits would depend on a very high proportion of the catchment land areas being planted with perennial species such as lucerne; this is unlikely as the optimal proportion of the farm planted to lucerne varies from only 0-30%.

Profitability Gain
Successful incorporation of lucerne into cropping systems can take various forms and can be complex to evaluate. These investments did demonstrate that lucerne could be quite profitable (more so in some regions than others). The major benefit was a higher level of profitability in mixed cropping farms where lucerne enhanced both the productivity of the livestock system and the whole farming system, despite both negative (through dewatering the soil profile in dry years leading to reduced yields) and positive impacts (mainly through providing disease breaks and adding nitrogen) on the specific cropping system involved.

Robertson (2006) reports profitability estimates from economic modelling across a range of regions where lucerne might be established in both Western Australia and in other southern states. This data (shown in Table 12) has been the major source of information used to estimate the increase in net farm profitability from lucerne in the current analysis.

Table 12: Increase in Profitability from Integration of Lucerne into Farming Systems in WA

Region	Area of lucerne in 2001 (ha)	Livestock system to utilise lucerne	Percentage lucerne assumed	Added income pa per whole farm ha ($ per ha)	Added income pa per lucerne ha ($ per ha)
WA Central Wheat Region	48,000	Merinos plus first cross lambs	12	3	25
WA South West	74,000	Specialist Wool	25	20	80
WA South Coast	28,000	Wool	20	8	40

Source: Robertson (2006)

In line with the above estimates, Kingwell (2003) reports that phase rotations that incorporate lucerne or lucerne rows with crop interows are both profitable systems. In many situations lucerne has boosted annual farm profit by $1 to $20 per ha of farm arable area, in spite of lucerne being planted on only a small area of the farm. A current estimate is that the whole farm profitability of lucerne in WA's south coast is now estimated at only $1 per total farm ha due to the fall in livestock product prices (David Hall, pers. comm., August 2008).

Another study involved an economic analysis of the introduction of lucerne into case study farms in Victoria and showed that the average livestock gross margin increased by $106 per ha, with a range of $58 to $143 per ha (Ransom et al., 2006). Assuming no net change on overall crop gross margins, the $106 per ha increase translated to about $56 per ha (crop area was an average of 47% of total farm area) on a whole farm basis. Lucerne made up about 25% of the total farm area on these farms so that the gross margin increase due to lucerne is estimated at $224 per ha of lucerne planted.

Over a 7 year period on a whole farm cash flow basis the average profit increase was $93 per ha for one of the Victorian case study farms that had planted 40% of the farm to lucerne, equivalent to $232 per ha of lucerne planted. While the crop gross margin increased on a number of farms, on others it declined. Allowing for the fact that these case study farms may achieve higher profitability than the average, a net annual benefit of $100 per ha of lucerne is assumed from lucerne establishment on mixed cropping farms in the northern region of Victoria.

Land Area Potentially Benefiting

Incorporating lucerne into cropping rotations has now provided additional information for growers to make better decisions than hitherto but its use from period to period may be dependent on the health of livestock industries and the relative price for grain and other crops (both summer and winter crops). Over the past few years, limited areas of lucerne have been planted in most regions due to the favourable grain prices and relatively low prices for livestock products.

The area of lucerne by State reported in the 2000/01 agricultural census is shown in Table 13.

Table 13: Area of Lucerne by State

State	Area (ha)
NSW	1,941,961
VIC	332,167
QLD	207,851
SA	559,265
WA	176,751
TAS	16,276
NT	82
ACT	1,048
TOTAL	3,235,400

The 2005/06 ABS census did not collect data on lucerne area for pasture; the area has been incorporated into 'hay pasture cereal and other crops cut for hay" and the lucerne pasture component can not be separated out (Anon, ABS, pers. comm., August 2008). This makes it difficult to assess how lucerne areas have changed since 2001.

The principal areas influenced predominantly by the cluster investment that may potentially benefit from integration of lucerne into cropping systems are provided in Robertson (2006) and are summarised in Table 14. The "Other" category includes all other areas suitable for lucerne as indicated in the footnote to the table.

Table 14: Agricultural Areas that May Potentially Benefit from the Investment in the Cluster

Region	Central Wheat Belt (WA)	South West (WA)	South Coast (WA)	SW Slopes NSW and Riverine Plains NSW/VIC	Other (a)
Area of agricultural land (m ha)	5.2	4.0	3.4	9.0	19.1
Area suitable for lucerne on basis of soils and climate (m ha)	2.5	2.6	2.1	7.65	13.6

(a) Includes Wimmera/Mallee (three States), SA, and Central West of NSW
Source: Robertson (2006)

Adoption
Table 15 shows the assumptions regarding adoption rates due the investment.

Table 15: Assumed Adoption Rate of Lucerne with and Without the Investment

Region	**Central Wheat Belt (WA)**	**South West (WA)**	**South Coast (WA)**	**Northern Victoria**	**Other (c)**
Estimate of area of lucerne in region in 2001 (ha)	48,000 (a)	74,000 (a)	28,000 (a)	100,000 (b)	1,940,000
Average annual growth rate of area of lucerne compared to existing area without investment (d)	2% pa	2% pa	2% pa	2% pa	2% pa
Average annual growth rate of lucerne compared to existing area with investment (d)	2.5% pa	2.5% pa	2.5% pa	2.5% pa	2%

(a) Source: Robertson (2006)
(b) Agtrans estimate
(c) Includes Wimmera/Mallee (SA and Vic) 200,000 ha; Mid North and Yorke Pen. (SA) 40,000 ha; SW Slopes and Riverine Plains (NSW and Vic) excluding Northern Vic 700,000 ha; and Central West 1,000,000 ha (Source: Robertson, 2006)
(d) Estimate by Agtrans; average annual adoption rate estimates assumed take into account the variability of planting from year to year due to fluctuating prices.

From the assumptions made in the above table, an increase in lucerne area per annum due to the investment of 1,250 ha.

Summary of Assumptions

A summary of the key assumptions made is shown in Table 16.

Table 16: Summary of Assumptions

Variable	**Assumption**	**Source**
Profitability Improvement from Lucerne		
Increase in gross margin per ha of lucerne established taking into account pasture/lucerne establishment costs and for different livestock systems	See Table 12 for assumptions by region	Agtrans based on Robertson (2006), Ransom et al (2006) and Kingwell (2003)
Adoption		
Existing areas of lucerne by regions influenced by the cluster investment	See Table 15 for assumptions by region	Agtrans base don Robertson (2006) See Table 13
Adoption rates with and without investment	See Table 15	Agtrans estimates
Overall annual average increase in lucerne area due to the investment	1,250 ha per annum	Derived from Table 15

Results

All past costs and benefits were expressed in 2006/07 dollar terms using the CPI. All benefits after 2006/07 were expressed in 2006/07 dollar terms. All costs and benefits were discounted to 2006/07 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 25 years from the last year of investment (2004/05) to the final year of benefits assumed (2029/30).

Investment criteria were estimated for both total investment and for the GRDC investment alone. Each set of investment criteria were estimated for different periods of benefits. The investment criteria were all positive (or other) as reported in Tables 17 and 18.

Table 17: Investment Criteria for Total Investment and Total Benefits (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits (m$)	1.06	4.06	8.12	12.64	17.23	20.78
Present value of costs (m$)	13.99	13.99	13.99	13.99	13.99	13.99
Net present value (m$)	-12.93	-9.93	-5.87	-1.35	3.24	6.79
Benefit cost ratio	0.08	0.29	0.58	0.90	1.23	1.49
Internal rate of return (%)	Negative	Negative	Negative	4.1	6.6	7.7

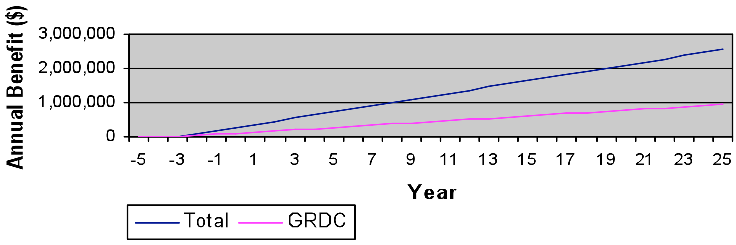
Table 18: Investment Criteria for GRDC Investment and Benefits to GRDC

(discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits (m$)	0.39	1.50	3.01	4.68	6.38	7.70
Present value of costs (m$)	5.19	5.19	5.19	5.19	5.19	5.19
Net present value (m$)	-4.80	-3.68	-2.18	-0.51	1.19	2.51
Benefit cost ratio	0.08	0.29	0.58	0.90	1.23	1.48
Internal rate of return (%)	Negative	Negative	Negative	4.1	6.6	7.7

The cash flow of benefits is shown in Figure 1 for both the total investment and for the GRDC investment in the cluster.

Figure 1: Annual Benefit Cash Flow



Sensitivity Analyses
Sensitivity analyses were carried out on several variables and results are reported in Tables 19 and 20. All sensitivity analyses were performed using a 5% discount rate with benefits taken over the life of the investment plus 25 years from the year of last investment. All other parameters were held at their base values.

Table 19 shows the investment criteria when the profitability assumption in each region is increased or decreased by 25%.

Table19: Sensitivity to Changes in Profitability of Integrating Cropping with Lucerne
(GRDC investment, 5% discount rate, 25 years))

	Level of Profitability from Lucerne		
Criterion	25% lower	Base	25% higher
Present value of benefits (m$)	5.77	7.70	9.62
Present value of costs (m$)	5.19	5.19	5.19
Net present value (m$)	0.58	2.51	4.43
Benefit cost ratio	1.11	1.48	1.85
Internal rate of return (%)	5.7	7.7	9.3

The adoption rates with and without investment are considered the most uncertain assumptions that have been made in the analysis. Table 20 shows the investment criteria for when the assumptions for adoption are doubled or halved.

Table 20: Sensitivity to Changes in Adoption Rates
(GRDC investment, 5% discount rate, 25 years)

	Adoption Rates for Lucerne		
Criterion	Half Base	Base	Twice Base
Present value of benefits (m$)	3.85	7.70	15.40
Present value of costs (m$)	5.19	5.19	5.19
Net present value (m$)	-1.4	2.51	10.21
Benefit cost ratio	0.74	1.48	2.97
Internal rate of return (%)	3.1	7.7	13.3

These sensitivity results show that the positive investment criteria for the base assumptions are reasonably robust to fairly significant changes to the two key assumptions.

8 Conclusions and Lessons Learned

The most important output from the investment was the extension of the knowledge base for integrating lucerne into farming systems in cropping regions. The investment has raised awareness of opportunities and potential profitability and provided greater confidence for cropping farmers to invest in lucerne as a deep rooted perennial.

One of the more important lessons from this assessment has been the lack of time series data on lucerne areas in grain growing areas. Given that the last investment was it the year 2004/05, it would have been advisable to ensure that ABS collected in the 2005/06 Census the same information as had been collected in 2000/01. However, it is not known if GRDC was consulted on what was being changed in the 2005/06 ABS Agricultural Census.

Assumptions are difficult to make regarding likely adoption of lucerne and its integration into cropping systems. From the analyses undertaken elsewhere there appears little doubt that, depending on individual circumstances, that increased whole farm profitability is likely. Nevertheless, successful adoption will depend on the actual farming system employed and there are still major reasons why lucerne is not being widely incorporated into cropping systems.

Based on a conservative estimate of the profitability gain likely and the area that has been, and will be, planted to lucerne over the next twenty years as a result of the R&D, the investment is considered to have been profitable with a net present value estimated at $6.8 m for the total investment and $1.5 m for the GRDC investment. The investment is estimated to provide a benefit-cost ratio of 1.5 and an internal rate of return of just below 8%.

These estimates are considered conservative since some potential environmental benefits have not been valued due to a lack of data supporting these linkages.

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